DOCUMENT RESUME

ED 059 104 SE 013 403

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TITLE Teaching Upper Elementary Science Using Theory-Laboratory Sequence and Laboratory-Theory Sequence Methods of Instruction. Final Report.
INSTITUTION Graceland Coll., Lamoni, Iowa.
SPONS AGENCY National Center for Educational Research and Development (DHEW/OE), Washington, D.C.
BUREAU NO BR-1-G-022
PUB DATE 15 Dec 71
GRANT OEG-7-71-0011(509)
NOTE 73p.

EDRS PRICE MF-$0.65 HC-$3.29
DESCRIPTORS Atomic Structure; *Cognitive Processes; *Concept Formation; Educational Research; *Elementary School Science; Evaluation; Scientific Concepts; *Teaching Methods

ABSTRACT

This study compared the relative effectiveness of teaching selected science concepts associated with the study of atoms and molecules to fourth and sixth grade students, using two contrasting teaching methods: (1) laboratory-theory sequence, and (2) theory-laboratory sequence. The sample of 99 students in one school was taught the science units through method (1), and 158 students in another school were taught the same science concepts using method (2). Analysis of covariance techniques were used, with IQ and general science achievement as covariates. Findings included the following: the laboratory-theory sequence method was a better way to teach science concepts in the fourth grade; the theory-laboratory sequence method was a better way to teach science concepts in the sixth grade; the concepts taught were too difficult for most fourth grade students but not too difficult for sixth grade students; concept retention after three months was extremely high for most of the students; sixth grade boys in the theory-laboratory sequence method scored significantly higher than girls; and there was no significant interaction between the treatment groups and IQ ability groupings. (Author/PR)

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Final Report

Project No. 1G022
Grant No. OEG-7-71-0011(509)

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TEACHING UPPER ELEMENTARY SCIENCE USING THEORY-LABORATORY SEQUENCE AND LABORATORY-THEORY SEQUENCE METHODS OF INSTRUCTION

December 15, 1971

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Office of Education

National Center for Educational Research and Development
(Regional Research Program)

Abstract

Teaching Upper Elementary School Science Using Laboratory-Theory Sequence and Theory-Laboratory Sequence Methods of Instruction

Charles M. Emslie

Purpose

This study compared the relative effectiveness of teaching selected concepts associated with the study of atoms and molecules to fourth and sixth grade students using two contrasting teaching methods which were:

Method 1. Laboratory-theory sequence,
Method 2. Theory-laboratory sequence.

Method of Research

The sample of 99 students in the fourth and sixth grades of one school were taught the science unit by Method 1, and 158 students in the fourth and sixth grades of another school were taught the same science concepts using Method 2.

Analysis of covariance techniques were used with IQ and general science achievement as covariates.

Findings

This study indicated that:

1. The laboratory-theory sequence method was a better way to teach science concepts in the fourth grade.

2. The theory-laboratory sequence method was a better way to teach science concepts in the sixth grade.

3. The concepts taught were too difficult for most fourth grade students.

4. The concepts taught were not too difficult for sixth grade students.

5. Concept retention after three months was extremely high for most of the students.

6. Boys in the theory-laboratory sequence method scored significantly higher than girls in sixth grade.

7. There was no significant interaction between the treatment groups and IQ ability groupings.

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The research reported herein was performed pursuant to a grant with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Governemnt sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
National Center for Educational Research and Development

Preface

I am indebted to Dr. Burton E. Voss, professor of science education at the University of Michigan, who gave valuable assistance in every phase of the project and to Dr. Finley Carpenter for his help in developing the research design.

The evaluation instrument used to measure student achievement was reprinted from Science: A Modern Approach, Book 6 by A. S. Fischler, L. F. Lowery and S. S. Blanc published by Holt, Rinehart and Winston, Inc. under the copyright date of (c) 1967. Permission has been obtained which permits use for U.S. Governmental purposes, including dissemination through the ERIC system. Any subsequent reproduction of the copyrighted portions of ERIC documents by ERIC users requires the permission of the copyright owner.

Also I want to acknowledge the enthusiastic support given by the administration, faculty and students in the Mount Ayr Community School system and the South Harrison School District R-11. The personnel of both elementary schools were most cooperative in making the necessary adjustments in their regular classroom procedures so that the experimental teaching and testing could be completed in the allotted time.

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CHAPTER I INTRODUCTION

Research in science and technology produced a considerable body of new scientific knowledge during and after World War II. It became clear to many scientists and educators that, in order for students to master the necessary science course materials, and become competent in science, some changes would have to be made in the school science curricula. Since the science curriculum reform movement was initiated by physicists and college teachers,[1] it was natural that the high school science programs were changed first. It might have been better if they had started with elementary school science and worked up through the grades. Science, being sequential in nature, requires the necessary foundations for the mastery of higher levels of understanding. Thus, satisfactory achievement in senior high science depends upon adequate foundations in junior high science which, in turn, depends upon elementary science for adequate preparation. The new secondary science curricula were injected into an unprepared educational system. The students, teachers, laboratory facilities, and the system of evaluating achievement were geared to traditional courses in science and this may account for some of the inconsistent results in the achievement of students who have completed one of the new courses of study.[2]

The research designed to measure the new junior high science programs is limited and incomplete. However, there is a good possibility that the findings will be very much similar to those for senior high science. If it is true that the junior high sciences have not properly prepared students for the new secondary science, then it follows that the achievement in the new junior high science programs will be affected by the preparation provided by elementary science experience. Since the new elementary science materials are not complete, the majority of the students taking the new junior high courses will probably experience difficulty adjusting to the new approach. Thus it seems appropriate to study science teaching methods for the elementary school level.

Statement of the Problem

The problem investigated by this study was: What will be the relative achievement of fourth and sixth grade students on a science unit, atoms and molecules, when taught by theory-laboratory sequence or laboratory-theory sequence methods of instruction developed for this investigation?

Two sub-problems are:

1. At which grade-level can the concepts associated with atoms and molecules best be introduced to the students?

2. Will retention of the science concepts be greater for the students who were taught by the theory-laboratory sequence method of instruction or the laboratory-theory sequence method?

Related Literature

The literature contains very little information directly focused on the term "theory" but there is a vast amount dealing with the terms "concept" and "Conceptualization." Many authors use the term "conceptual scheme" which seems to approximate a common definition of the term "theory" given by Bruner.[3] The definitions for concept and conceptual scheme stated by Jenkins[4] are close to what is assumed to be the meaning intended in the literature when not specifically defined:

> "A concept is an idea based on a pattern of events. When the child understands the idea or attaches meaning to the pattern, he has attained the concept."

> "A conceptual scheme is a generalization made up of a group of related concepts as evidenced by a common element or characteristics among them."

Since there are almost no references in the literature that deal with theory specifically, the term "conceptual scheme" will be considered to have the same meaning as "theory" for understanding the related literature.

Can Children Learn Science Concepts?

A considerable amount of research has been conducted to determine whether or not elementary school children are capable of developing abstractions. There is general agreement among the authors that they are able to formulate mental models to explain their observations of natural phenomena. It is quite clear that concept development is central to the entire process of education, because "concepts are powerful intellectual tools which enable their possessor to cope efficiently and easily with the continuing flow of life's problems."[5] Heffernan[6] states that the teacher who is aware of the way concepts are developed will seek continually to provide children with a wide variety of sensory experiences. The results of a study of Anderson[7] indicates that it is plausible to teach science in a manner that permits children to become actively engaged in the process of formulating theoretical or mental models (concepts). Smith[8] points

out that elementary children are capable of learning concepts and that it is the teacher's task to help the children "develop concepts so that they become useful tools at a conscious level which can be verbalized and consciously and deliberately applied."

At What Age Should Science Concepts Be Taught?

The learning theory developed by Piaget[9] states that abstract thinking becomes possible when the child reaches adolescence. Extensive research on Piaget's theory has been conducted by several investigators with the conclusions being similar to those of Almy:[10]

> "Truly abstract thinking involving the ability to deal with the possible without reference to the actual, according to Piaget, is a later development. Not until he enters the final stage of formal operations, at the beginning of adolescence, can the young person construct theories and make logical deductions as to their consequences without the necessity for empirical evidence."

Ausubel is in agreement with this position.[11] Raven,[12] however, reporting on a study he did with children in the primary grades found that they were capable of developing the concept of momentum, which involved the concepts of conservation of matter, speed, and the proportional use of mass and speed. He states that on the average, children can conceptualize by the time they reach third grade. Young[13] found that children in the third and sixth grades were capable of developing concepts of atomic structure and the use of atomic energy. Harris[14] reported a significant difference in the ability of the experimental group over the control group of children in the fourth, fifth, and sixth grades, in a study specifically designed to measure the mental age of children capable of science conceptualization. He also found that mental age is one of the variables affecting the ability of the child to develop science concepts. In his study the average and high ability groups showed significant gains after instruction in science concepts, but the low ability group did not. Pella and Carey[15] conducted a study to determine the relative levels of understanding of certain concepts within the conceptual scheme, "the particle nature of matter," achieved by children in grades two through five. They found that out of a total of 16 concepts, 11 were mastered by the above-average fourth grade students and 15 concepts were mastered by the above-average fifth graders. The above-average second grade children mastered 2 concepts and the above-average third grade children mastered 4 concepts.

What Teaching Methods Are Used?

The methods of teaching science most often investigated by research are "discovery" learning (direct experience in the laboratory) and lecture-demonstration. The laboratory centered method has received considerable attention in current research because the new science curricula have developed materials centered around the laboratory experience.

There are an increasing number of research projects being reported in the current educational journals on effective ways of teaching science concepts at the elementary school level. In a study reported by Butts,[16] who was measuring the degree to which children conceptualize from experiences in science, there was no consistent significant concept development when the individual manipulation method was used. His subjects were fourth, fifth, and sixth grade students who voluntarily participated in the experience on an after school science class basis. The students were confronted with a phenomena in a science experience, and little else. The students were allowed to do what they wanted to in the experience except discuss the experience with other class members. All the experiences were centered around four concepts which were: Displacement; Inertia; Action-Reaction; and Depth-Pressure Relationship. Butts observed that a certain amount of external direction was necessary for children prior to the ninth grade if self-discovery is to be rewarding and motivating. He summed it up this way:

> "Although the evidence from this study causes us to question seriously the adequacy of independent manipulation of data as being sufficient for concept development, we do not mean to infer that it has no importance. Further study is needed to determine what factors in addition to first-hand experience will aid the child to develop conceptual understanding."

In another study Butts[17] used very bright fourth, fifth, and sixth grade children to see whether or not experience in science was equal to understanding. He found that when the equation consisted of experience plus independence of manipulation there was no significant progress in understanding. But when he added direction to the experience and manipulation, there was a significant change in their understanding. He explained direction this way:

> "The teacher is not telling the student or playing the role of information giver. The teacher is classifying the relationships within the students experience in such a way that he is motivated to continue to search for understanding. The attitude

of the teacher in this intellectual guidance may well be the most important determining factor of future cognitive growth of the student."

Pella and Voelker[18] carried out research in teaching the concepts of physical and chemical change to elementary school children in grades two through six. The experimental group formulated or discovered the generalization and the teacher formulated the generalizations in the control group. As a part of this study they were interested in determining whether the maturity of the learner was a factor contributing to the level of conceptual understanding. Their experiment indicated that there was no significant difference due to the treatment, but they did find that the understanding of the fourth, fifth, and sixth grade students was significantly greater than the second and third grade children. There was a significant relationship between the scores earned by pupils in grades two through six who received the treatment (teacher assumed the responsibility for formulating and stating the generalization) on the classification phase of the test and the number of times they supported correct classifications with correct reasons.

Retention of knowledge deserves consideration as a part of the total learning experience. Some research has been done focusing on retention in relation to teaching method. Gage and Bassler[19] studied 90 sixth grade students for retention of mathematical concepts and found that one of the best aids to memory was systematic review. Wittrock[20] in research conducted using college students found that explicit and detailed direction seems to be most effective when the criterion is initial learning of a few responses. Some intermediate amount of direction produced the best results when the criteria was retention and transfer of knowledge. Bruner [21] says that unless detail is placed into a structured pattern it is rapidly forgotten.

Research points to the fact that elementary school children are capable of learning concepts in science and the most appropriate age for conceptualizing the instruction seems to be in the upper elementary grades. The most effective way to teach science concepts is not clear from the literature partly because there is a lack of consistent, adequate definitions and terminology. Apparently retention of knowledge is facilitated by placing details in a structured pattern followed by frequent reinforcement.

<u>Purpose of the Study</u>

The purposes of this study are:

1. To determine the difference in achievement of students taught the concepts associated with atoms and molecules by the contrasting methods of theory-laboratory sequence and laboratory-theory sequence methods of instruction as measured by a validated objective post test instrument.

2. To determine the proper grade placement for instruction in the theoretical concepts associated with atoms and molecules.

3. To determine student retention of selected concepts associated with atoms and molecules as measured on a delayed post test.

Statement of Hypotheses

The hypotheses to be tested are:

1. There will be no significant difference in the achievement of fourth and sixth grade students taught the concepts associated with atoms and molecules by the contrasting methods of a theory-laboratory sequence and a laboratory-theory sequence of instruction as measured by a validated objective post test instrument.

   1(a) Fourth grade students cannot learn adequately the science concepts associated with atoms and molecules where adequacy means that a certain number of the students must make correct responses to a specified number of the post test items.

   1(b) Sixth grade students cannot learn adequately the science concepts associated with atoms and molecules where adequacy means that a certain number of the students must make correct responses to a specified number of the post test items.

   1(c) There will be no significant difference between the achievement scores of fourth and sixth grade boys and girls measured at each grade level when taught selected science concepts associated with atoms and molecules by either a laboratory-theory or a theory-laboratory sequence method of instruction as measured by a validated post test.

   1(d) There will be no significant difference between achievement scores on the

post test items of the high, medium, and low IQ fourth and sixth grade students taught selected science concepts by a theory-laboratory sequence method and the differences in achievement scores on the post test items of the high, medium, and low IQ fourth and sixth grade students taught the same concepts by a laboratory-theory sequence method of instruction.

2. There will be no significant difference in the retention of concepts associated with atoms and molecules for students taught by the laboratory-theory sequence and the theory-laboratory sequence methods of instruction as measured by a delayed post test instrument administered three months after the post test.

The results of the statistical analysis are included with each hypothesis tested and the significance level for the rejection of the null hypotheses set at .05. That is, the null hypothesis was rejected if the results obtained would occur less than five percent of the time by chance.

Limitations of the Research

This research is limited to a study of fourth and sixth grade students located in the rural area of north central United States. The sample included six intact classrooms form one elementary school system and from intact classrooms from another school system located about sixty miles apart in south central Iowa and northern Missouri. The students in the classes of the two schools were essentially equivalent to each other in every observable respect. Both schools had heterogeneous ability groupings and self contained classrooms for all but the three sixth grade classes in the Missouri school system. The students in these three classes were taught by the same science teacher.

The statistical analysis was based on the achievement scores of a test instrument designed to be used with a sixth grade science test which included a unit entitled Atoms and Molecules. No statistical information was available on this instrument so it was submitted to a jury of science supervisors and high school and college chemistry and physics teachers for a validity check. Members of the panel considered the evaluation instrument difficult for fourth and sixth grade students. The panel agreed on the answers to 60 of the 91 items. Because the test was considered difficult it was decided that a satisfactory level of competence would be reached if about 50 percent of the group tested made correct responses to about 50 percent of the 60 items.

The 60 items selected by the jury panel were analyzed and a tabulation of the correct response percentages for each grade level is shown in Table 1 of Appendix D. This distribution indicates that the majority of the items were not partial to students of either method of instruction

Table 2 in Appendix D shows the data from a Chi Square analysis of the same 60 items. This tabulation shows that a total of eleven items were partial to one or the other methods of instruction at a confidence level of .05 or less. Six of the items significantly favored the laboratory-theory sequence students and five items favored the theory-laboratory sequence students.

The evaluation instrument used to measure student achievement was difficult and did not give a valid measure of what the fourth grade students had learned about the atomic structure of matter. Since the topic selected was theoretical in nature, the achievement test was clearly weighted with theory type items (see Appendix B). The experimental design provided equal amounts of time for both methods of instruction but not all the concepts developed could be observed in the laboratory. Thus, while the laboratory work was tested by the exam, there were fewer laboratory questions than theory questions. The total score for the sixth grade students, however, provided a measure of the treatment effect on their achievement.

The motivation for learning was noticeably high in both the fourth and sixth grade classes. This was primarily due to the fact that the instructor was a special science teacher, creating a different learning atmosphere in the classroom.

CHAPTER II PROCEDURES

Selection of Science Unit

The science unit selected to teach the fourth and sixth grade students was about atoms and molecules. This particular topic was selected because the theories associated with the atomic structure of matter are basic to all the sciences. Tamppari[22] found that physical science concepts are prerequisite to the learning of biology principles and that elementary children are not adequately exposed to physical, chemical, and general science. Also, the National Assessment of Educational Progress[23] in a summary of Report #1 indicated lower achievement in the physical sciences. An examination of ten elementary school science text series (Appendix C) revealed that two of the fourth grade and seven of the sixth grade texts treated topics related to atom and molecules in varying degrees of completeness. Only one (Holt, Rinehart and Winston, Inc., 1967) sixth grade text treated the topic in-depth with a considerable amount of atomic theory. Additional support for including this kind of a topic at the elementary school level is found in Ausubel's[24] statement:

> "Good teaching is as thorough as is possible at the appropriate level of breadth and depth; and even at the elementary school level it allows for the occasional introduction of atypical depth, both substantively and methodologically, to give the student a taste of scholarship and of research inquiry."

Variables Studied

The independent variables were two methods of teaching science (theory-laboratory sequence and laboratory-theory sequence methods of instruction) and grade level. The theory-laboratory sequence of instruction is defined as the sequence which develops detailed mental models and concepts of the structure of matter as they relate to atoms and molecules before performing laboratory experiments. Basic scientific definitions are established during this same period of instruction. The laboratory experiences serve as reinforcement and the student is led to discover interpretations of his observations in terms of his theoretical foundations.

The theory-laboratory sequence of instruction was selected as one method of instruction because educational research indicates that fourth and sixth grade students are capable of learning concepts and participating in abstract thinking[25,26]. Piaget[27] calls this stage the operational level of cognitive development which he places

at the beginning of adolescence. On the average, this coincides with the age of sixth grade students. This sequence of learning experience permits the acquistion of a wider variety of knowledge based on one theoretical conceptual scheme. Learning the theory first permits the learner to view an event with greater understanding and insight. Bruner[28] describes a theory and its uses this way:

> "A theory is far more and far less than an unproved statement of facts. It is something more than a generalization about what happens--or more than a statistical statement about what is more and what is less likely to happen. It is, rather, a formal model, a set of propositions about things and ways of reordering those propositions that generate from time to time, predictions about the world to which the theory hopefully relates. Armed with a theory, one is guided to things to look for and, if the theory is a good one at all, it whould provide one with a terse account of what is known without the burden of details. A theory is not only the fruit of experience with what is known, but a product of the imagination and careful fantasy in ways of expressing it so that one can go beyond the known. It is a canny way of keeping in mind a vast amount while thinking about a very little."

The theory-laboratory sequence of instruction does not rule out learning by discovery but in reality enhances it. Discovery is not restricted to the act of finding out something new "but rather includes all forms of obtaining knowledge for oneself by the use of one's own mind. Discovery, like surprise, favors the well prepared mind."[29] This preparation can come by learning the theoretical considerations first and then experiences of surprise may occur when new, related knowledge is encountered. Bruner[30] says that "discovery in its essence is a matter of rearranging or transforming evidence in such a way that one is enabled to go beyond the evidence so assembled to additional new insights." With a good foundation in theory, discovery becomes much more probable.

The laboratory-theory sequence method was selected as the second method of instruction because this is the traditional way elementary school science is taught. This method is usually thought of as going from the known to the unknown. In this sequence of instruction the concepts associated with atoms and molecules were introduced first by observing some physical or chemical changes in matter. Each experiment was followed immediately by a guided discovery of the concepts about atoms and molecules directly related to the observed changes. Another reason for using this method of instruction was that this sequence is recommended by the designers of many of the new junior and

senior-high school science programs recently published. These new programs place considerable emphasis on the laboratory and the discovery-inductive method of teaching and learning. In addition there is a considerable amount of research reported in the science journals favoring this approach to learning.[31]

The second independent variable was grade level. The fourth and sixth grades were selected because students in these grades would provide a contrast in age level and cognitive development.

The two dependent variables were the achievement and retention of fourth and sixth grade students as measured by an objective validated post and delayed post test instrument. A published test for this science unit was made available for these evaluations, (Appendix B).

Objectives

The objectives of this study were:

1. To determine the differences in achievement of students taught the concepts associated with atoms and molecules by the contrasting methods of theory-laboratory sequence and laboratory-theory sequence of instruction as measured by a validated objective post test instrument.

2. To determine whether instruction in the theoretical concepts associated with atoms and molecules is appropriate in grades four and/or six.

3. To determine the effect of the teaching method on student retention of the concepts associated with atoms and molecules as measured by a delayed post test.

Description of Treatment

First contact was made with both school systems in August of 1970 when preliminary arrangements were made with the school administration and teachers to conduct this research in their classrooms. The dates for the classroom instruction were agreed upon and a schedule was established for the investigator to visit each classroom several times prior to the formal classroom instruction. Also the text materials associated with the unit on atoms and molecules were identified and the teachers agreed to omit these materials from their lesson plans. In some cases the teachers made references to the materials omitted but there was no formal instruction on atoms and

molecules before or after the ten days of instruction associated with this research project.

Each classroom was visited by the investigator three times prior to the unit of instruction in an effort to become familiar with the students, the teachers, and the established classroom procedures. During the last visit at each school final arrangements were made with each classroom teacher involved in the project specifying the exact teaching schedule and explaining what their responsibilities would be during the teaching and testing phases of the project. Since they would not be involved in the actual teaching, they were asked to assist with the mechanics associated with the laboratory work and to help maintain a learning atmosphere in the classroom during the more informal periods of instruction.

Arrangements were also made with the administration and the guidance and counseling personnel to make available the necessary information from the cumulative records for all the students included in the sample.

All the classroom teaching for the selected science unit was done by the investigator. Based on his previous experience of teaching a similar science unit to fifth grade students in the University of Michigan Laboratory School, it was decided to have ten 40 minute class periods for each method of instruction.

The teaching phase of the research was completed during the month of January, 1971. The fourth and sixth grade classes in the Iowa school system were taught the science unit during the first two weeks using the laboratory-theory sequence method of instruction. The fourth and sixth grade students of the Missouri school system received the theory-laboratory sequence method of instruction during the last two weeks of the month. The delayed post test was given three months later.

It was considered important to use the same 25 laboratory experiments for both methods of instruction. The investigator chose to use the laboratory-theory sequence of instruction in the first school in order to work out the management problems associated with performing laboratory experiments in the regular classroom. The ten days of experience in the first school proved to be very valuable preparation for the classroom instruction in the second school where the same laboratory experiments were completed in five periods. There were many complications associated with the laboratory work which were not anticipated when the lesson plans were developed. Of major importance was the time factor associated with passing out and collecting the equipment and supplies for each student.

After the first period of the laboratory-theory sequence of instruction the lesson plans were modified to include only those experiments which clearly supported the theories considered most important to the study of atoms and molecules.

Each one of the ten lessons using the laboratory-theory sequence method of instruction started with a laboratory experiment. The students were either given some equipment and materials and asked to perform some specific experiment or several of the students were selected to conduct a laboratory demonstration illustrating changes which could be explained by the atomic theory. After the experiment was completed the explanation of what probably took palce to produce the observed changes was discussed with the class. Since there were a total of 25 experiments it was necessary to perform two or three experiments each class period. The detailed final lesson plans for both the laboratory-theory sequence and the theory-laboratory sequence methods of instruction are in Appendix A.

In the second school system where the theory-laboratory sequence method of instruction was used the time factor proved to be most critical. There were three fourth and three sixth grade classes participating in the project and the school day was divided into a total of nine 40 minute periods. Because of special scheduling for art, music, physical education, and reading there were some minor adjustments in the regular science instruction period reserved for each class. As a general rule, the three fourth grades had their science the first three periods in the morning and the three sixth grade classes had their science the first three periods after lunch. This corresponded to the time schedule for the science periods in the first school.

The theory-laboratory sequence method of instruction began with five periods devoted to the discussion of the theories associated with the atomic structure of matter. The students were exposed to the theories associated with three fundamental forces (gravity, electric and magnetic), the fundamental atomic particles (electrons, protons and neutrons), the relative mass of each particle, the way the particles are combined to form the different chemical elements, how compounds are formed, and the idea that there are spaces between the atoms and molecules in all matter. In general each lesson started with a review of the concepts introduced in the previous lesson, followed by an inquiry session, a film, or a simple demonstration by the investigator to focus attention upon the new lesson materials. These activites were limited to mental exercises.

With the help of the periodic chart of chemical elements, most of the students were able to identify the fundamental particles necessary to make models of the first eight elements on the periodic table by the end of the fifth period. During the fifth period each student constructed an atomic model of one of the first eight elements shown on the chart. A water molecule model was made and placed above the chalkboard in each classroom and used for reference during the next five periods.

The remaining five periods were devoted to laboratory experimentation. The same 25 experiments used in the first school system were completed here in five periods; thus it was necessary to perform several experiments during each class session. Some experiments were performed by each student and others were performed by half the class as a demonstration for the remainder of the class. In all cases the atomic concepts and theories revealed in the experiments were identified and discussed by the class.

The Evaluation of Achievement and Learning

The appropriate Stanford Achievement Test, Intermediate I or II, Form W was administered about the same time in both school systems by the regular classroom teacher or the school counselor. The scores on the science section of the test were used as a measure of each students' general knowledge in science.

The instrument used for the post and delayed post test was a published test designed for the unit entitled Atoms and Molecules in the Holt, Rinehart and Winston science text, Science: A Modern Approach, Book Six published in 1967, (Appendix B). The post test was administered during the two succeeding science periods on the two regular school days following the ten days of formal instruction. Part I started with the section entitled Comparisons on page two of the test booklet and ended with the items in the section entitled Fact and Theory. Part II began with the section entitled Elements and Compounds and continued to the end of the test booklet. The items on page one were included as the last section of Part II because they were considered to be the most complex. The test was duplicated and a copy given to each student so that he could read the items and make his responses in the test booklet. The students also heard each item read twice by means of an audio tape prepared for this research by an assistant who was a certified elementary school teacher. This audio-visual method of testing was used to obtain a better measure of science achievement by minimizing the reading ability variable known to exist at these grade levels. Bond and Tinker[32] report a normal range of reading ability from a 1.7 to 6.5 grade level in the fourth grade and from a 2.5 to 9.5 grade level in the sixth grade.

CHAPTER III RESULTS

The data obtained from this research were tabulated and punched into computer cards. All of the statistical analysis was done by an IBM 360/67 computer programmed to test the Null hypotheses.

Hypothesis 1

Analysis of covariance was used to test the first hypothesis. In this design the independent variables were the two grade levels and the two methods of instruction. The three dependent variables were the achievement scores on the post test and identified as total, laboratory, and theory items. In all cases the score represented the total number of correct responses to the test items in each category. From the items included in the total, a set of items was selected which the investigator considered would favor the student who had had the laboratory-theory sequence method of instruction and these were called laboratory items. A second set was identified as theory items which would favor students taught by the theory-laboratory sequence method of instruction.

The student IQ and general science achievement scores were covariates and controlled in the analysis. The adjusted means obtained were used rather than the observed means in order to increase the precision of the analysis.

Three separate computer analyses were performed on the experimental data. The first computer run used the method of instruction as the independent variable and compared the differences in adjusted means of the combined fourth and sixth grade students in the laboratory-theory sequence groups with the differences in the adjusted means of the combined fourth and sixth grade students receiving the theory-laboratory sequence method of instruction.

The data in Table 1 shows that the achievement of the theory-laboratory sequence students was not significantly higher than the achievement of the laboratory-theory sequence students. This analysis used the total sample and compared the achievement scores of all the fourth and sixth grade laboratory-theory sequence students with all the fourth and sixth grade theory-laboratory sequence students.

The second and third computer runs compared the achievement scores for the fourth and sixth grade students separately. Each analysis measured the effect of the teaching method on the achievement of the students at each grade level.

TABLE 1

ADJUSTED GROUP MEANS OF POST TEST SCORES FOR BOTH FOURTH AND SIXTH GRADE STUDENTS ARRANGED ACCORDING TO TREATMENT METHOD (N=239)

Items	Laboratory-Theory	Theory-Laboratory	F-Value	Significance Level
Total	26.340	25.538	0.022	0.883
Lab	10.298	9.938	0.000	0.987
Theory	11.734	11.697	0.766	0.382

*$p < .05$ (df 1,235; F=3.88)

**$p < .01$ (df 1,235; F=6.74)

TABLE 2

ADJUSTED GROUP MEANS OF THE POST TEST SCORES FOR THE FOURTH GRADE STUDENTS ARRANGED ACCORDING TO TREATMENT (N=123)

Items	Treatment		F-Value	Significance Level
	Lab-Theory	Theory-Lab		
Total	23.319	21.965	3.284	0.073
Lab	8.546	8.284	0.281	0.597
Theory	11.211	10.303	4.754*	0.031

*$p < .05$ (df 1,119; F=3.93)

**$p < .01$ (df 1,119; F=6.87)

Table 2 shows the tabulation of the results obtained for the fourth grade students. These data indicate that the fourth grade pupils receiving the laboratory-theory sequence method of instruction achieved higher scores on the post test than the students receiving the theory-laboratory sequence method os instruction. There was a significant difference in the adjusted means identified as theory items and the difference in the adjusted group menas of the total score reached a .07 level of confidence. There was no significant difference in the adjusted means identified as laboratory items.

The data recorded in Table 3 shows the effect of the teaching methods on the adjusted group means of the achievement scores of the sixth grade students. These data revealed that the sixth grade students receiving the theory-labloratory sequence method of instruction scored higher on the post test than the students in the laboratory-theory sequence group. There was a significant difference in the adjusted mean scores identified as theory items and the difference in the adjusted means of the total score reached a .06 level of confidence.

TABLE 3

ADJUSTED GROUP MEANS OF THE POST TEST SCORES FOR THE SIXTH GRADE STUDENTS ACCORDING TO TREATMENT (N=120)

Items	Treatment: Lab-Theory	Treatment: Theory-Lab	F-Value	Significance Level
Total	28.068	29.954	3.676	0.058
Lab	11.484	11.926	0.768	0.383
Theory	11.844	13.394	7.446**	0.007

*p<.05 (df 1,116; F=3.93)

**p<.01 (df 1,116; F=6.87)

TABLE 4

FREQUENCY DISTRIBUTION OF CORRECT ITEM RESPONSES
FOR THE FOURTH AND SIXTH GRADE STUDENTS

Fourth Grade (N = 126)

Score	Frequency
30	1
22	1
21	1
20	3
19	4
18	2
17	6
16	9
15	8
14	15
13	12
12	12
11	14
10	9
9	13
8	6
7	3
6	4
5	2
4	1

X = 12.611

SD = 4.00

r* = 0.549

*Kuder-Richerdson Reliability Coefficient.

Sixth Grade (N = 131)

Score	Frequency
47	1
46	1
44	1
43	2
41	1
40	6
39	4
37	2
36	5
35	5
34	2
33	7
32	7
31	6
30	10
29	5
28	11
27	9
26	8
25	3
24	8
23	3
22	7
21	5
20	5
19	4
18	2
14	1

X = 29.183

SD = 6.632

r* = 0.725

Guilford[33] states that the reliability coefficient applies to a certain instrument administered to a certain pupulation under certain conditions and indicates the difficulty level of the instrument for the sample tested. The value of .55 shows that the instrument was difficult for the fourth grade students and there would be a 50 percent chance that the same students would not repeat their scores in a test re-test situation. From these data it was concluded that this sample of fourth grade students was not capable of understanding the concepts associated with this unit of instruction.

The data on the sixth grade students shown in Table 4 indicated competency. The mean score was 29.18; 65 of the 131 students in the sample achieved a score of 29 or more which is evidence that this group of sixth grade pupils met the established criteria. The reliability coefficient of .73 also indicated that these students would reproduce about the same score in a controlled test re-test situation.

The analysis of the difference in adjusted means of the fourth and sixth grade students is shown in Table 5.

TABLE 5

ADJUSTED GROUP MEANS OF POST TEST SCORES FOR THE TOTAL SAMPLE ARRANGED ACCORDING TO GRADE LEVEL AND TREATMENT METHOD (N=249)

	Fourth Grade		Sixth Grade		Between Grades
Items	Lab-Theory	Theory-Lab	Lab-Theory	Theory-Lab	F-Value
Total	25.149	23.769	26.400	28.139	6.845**
Lab	9.222	8.944	10.820	11.293	1.191
Theory	11.942	11.047	11.204	12.628	11.452**

*$p < .05$ (df 3,244; F=2.64)

**$p < .01$ (df 3,244; F=3.86)

These data indicate that differences between the post and delayed post test scores of the fourth and sixth grade students in the theory-laboratory sequence method of instruction was significantly higher than the differences between the post and delayed post test scores of the laboratory-theory sequence groups. This was true for the total score and those identified as theory items but not for those identified as laboratory items.

TABLE 6

ADJUSTED GROUP MEANS OF POST TEST SCORES FOR THE FOURTH GRADE STUDENTS RECEIVING THE LABORATORY-THEORY SEQUENCE METHOD OF INSTRUCTION (N=46)

Items	Boys	Girls	F-Value	Significance Level
Total	24.155	22.673	1.506	0.267
Lab	8.971	8.177	1.165	0.287
Theory	11.928	10.466	3.968	0.053

*$p<.05$ (df 1,42; F=4.06)

**$p<.01$ (df 1,42; F=7.24)

The data used to test subhypothesis 1(c) are included in Tables 6 through 9. This analysis indicated that there was no statistically significant difference between the adjusted mean scores of boys and girls in the fourth and sixth grade laboratory-theory sequence method of instruction or in the theory-laboratory sequence method of instruction for the fourth grade students. The analysis of the sixth grade theory-laboratory sequence students adjusted mean scores showed a significant difference in the total score and those identified as theory items. The achievement of the sixth grade boys was significantly higher than the sixth grade girls for this teaching method.

TABLE 7

ADJUSTED GROUP MEANS OF POST TEST SCORES FOR THE FOURTH GRADE STUDENTS RECEIVING THE THEORY-LABORATORY SEQUENCE METHOD OF INSTRUCTION (N=73)

Items	Boys	Girls	F-Value	Significance Level
Total	22.143	22.000	0.024	0.878
Lab	8.390	8.181	0.102	0.751
Theory	10.415	10.341	0.024	0.879

*p<.05 (df 1,69; F=3.98)

**p<.01 (df 1,69; F=7.01)

TABLE 8

ADJUSTED GROUP MEANS OF POST TEST SCORES FOR THE SIXTH GRADE STUDENTS RECEIVING THE LABORATORY-THEORY SEQUENCE METHOD OF INSTRUCTION (N=48)

Items	Boys	Girls	F-Value	Significance Level
Total	28.676	29.400	0.303	0.585
Lab	11.341	12.364	2.240	0.142
Theory	12.286	12.111	0.036	0.851

*p<.05 (df 1,44; F=4.06)

**p<.01 (df 1,44; F=7.24)

TABLE 9

ADJUSTED GROUP MEANS OF POST TEST SCORES FOR THE SIXTH GRADE STUDENTS RECEIVING THE THEORY-LABORATORY SEQUENCE METHOD OF INSTRUCTION (N=72)

Items	Boys	Girls	F-Value	Significance Level
Total	30.160	27.563	4.159*	0.045
Lab	11.834	11.283	0.681	0.412
Theory	13.690	12.153	5.337*	0.024

*$p < .05$ (df 1,68; F=3.98)

**$p < .01$ (df 1,68; F=7.01)

The effect of the treatment on students in high, medium, and low IQ ability groups was also measured by analysis of covariance and the resulting data are recorded in Tables 10 and 11. The analysis was made by grade level and was used to test Subhypothesis 1(d). These data revealed only small differences in adjusted mean scores of fourth grade students in the laboratory-theory sequence method compared with the theory-laboratory sequence students when separated into high, medium, and low IQ ability groupings. There was a statistically significant difference in the adjusted means in the differences between the high and low IQ groups and in the differences between the medium and low IQ groups for the post test scores identified as theory items. There were no statistically significant differences in any of the ability groupings for the sixth grade students.

TABLE 10

ADJUSTED GROUP MEANS OF POST TEST SCORES FOR THE FOURTH GRADE STUDENTS BY TREATMENT METHOD FOR LOW, MEDIUM, AND HIGH IQ ABILITY (N=121)

Items	Laboratory-Theory			Theory-Laboratory			F-Values		
	High	Medium	Low	High	Medium	Low	Hi-Med	Hi-Low	Med-Low
Total	24.640	23.180	22.158	21.540	21.670	22.707	0.743	3.77	1.273
Lab	8.533	8.105	9.030	8.056	7.997	8.820	0.089	0.045	0.007
Theory	12.403	11.300	9.415	10.769	9.940	10.181	0.051	5.544*	7.047**

*$p < .05$ (df 1,115; F=3.94)

**$p < .01$ (df 1,115; F=6.90)

TABLE 11

ADJUSTED GROUP MEANS OF POST TEST SCORES FOR THE SIXTH GRADE STUDENTS BY TREATMENT METHOD IN HIGH, MEDIUM, AND LOW IQ ABILITY GROUPS (N=124)

Items	Laboratory-Theory			Theory-Laboratory			F-Value		
	High	Med	Low	High	Med	Low	High	Med	Low
Total	29.379	28.027	27.422	30.872	28.601	29.960	0.172	0.206	0.743
Lab	10.520	11.345	11.996	11.532	11.863	12.864	0.187	0.015	0.089
Theory	12.743	11.125	12.097	14.177	12.491	13.258	0.003	0.043	0.025

*$p < .05$ (df 1,112; F=3.94)

**$p < .01$ (df 1,112; F=6.90)

Hypothesis 2

Analysis of covariance was used to test the second hypothesis. In this research design the independent variables were the two grade levels and the two methods of instruction. The two dependent variables were the total achievement scores on the post and delayed post tests. In all cases the scores used represented the total number of correct responses to the test items. The students' IQ and general science achievement scores were covariates and controlled in this snalysis. The adjusted means were used rather than the observed means to increase the precision of the analysis.

The differences in the adjusted means of the post and delayed post test scores were compared by grade level and treatment method. Table 12 indicates no statistically significant difference in either the fourth or sixth grade mean scores of the post and delayed post test adjusted means for each grade level.

Table 13 provides a comparison of the adjusted means for the post and delayed post test scores for the fourth and sixth grade students separately. The delayed post test scores were consistenly higher than the post test scores for all but two of twelve scores compared. Theese higher scores indicated the possibility that the students in both methods of instruction were learning the concepts and the application of principles associated with the atomic theory rather than facts about atoms and molecules.

TABLE 12

COMPARISON OF ADJUSTED MEANS FOR THE DIFFERENCES IN POST AND DELAYED POST TEST SCORES COMPARING FOURTH GRADE LAB-THEORY STUDENTS WITH FOURTH GRADE THEORY-LAB STUDENTS AND SIXTH GRADE LAB-THEORY STUDENTS WITH SIXTH GRADE THEORY-LAB STUDENTS

Sample Size	Degrees of Freedom	Grade Level	Adjusted Group Mean Scores		F-Value	Significance Level
			Lab-Theory	Theory-Lab		
119	1,115	4	1.089	0.232	0.878	.351
120	1,116	6	0.425	0.300	0.016	.899

TABLE 13

ADJUSTED GROUP MEANS OF THE POST AND DELAYED POST TEST SCORES FOR THE FOURTH AND SIXTH GRADE STUDENTS ACCORDING TO TREATMENT METHOD

Test	Items	Fourth Grade (N=123)		Sixth Grade (N=120)	
		Lab-Theory	Theory-Lab	Lab-Theory	Theory-Lab
Post	Total	23.319	21.965	28.068	29.954
	Lab	8.546	8.284	11.484	11.926
	Theory	11.211	10.303	11.844	13.394
Delayed Post	Total	24.485	22.366	28.460	30.041
	Lab	9.410	8.591	*11.118	12.186
	Theory	*11.180	10.571	12.603	13.487

*Lower delayed post test score

CHAPTER IV CONCLUSIONS

There was no significant difference in the total achievement scores for the fourth grade students due to the teaching sequence. The data indicated an overall tendency favoring the laboratory-theory sequence as the preferred method of instruction. It was assumed that the laboratory experiences created a high motivation for learning theoretical concepts.

There was no significant difference in the total achievement scores for the sixth grade students due to the teaching sequence. The data indicated that the sixth grade students more readily accepted the concepts without laboratory motivation.

This study indicated that the concepts associated with aotms and molecules were not learned adequately by the majority of fourth grade students in this sample.

This study indicated that sixth grade students in this sample were able to learn the concepts associated with atoms and molecules.

Retention of the concepts associated with atoms and molecules as measured by a delayed post test three months after the post test was extremely high.

This study indicated that sixth grade boys in the theory-laboratory sequence group scored significantly higher on the total post test items than the sixth grade girls in the same group.

This study indicated that there was no significant interaction between the treatment groups and IQ ability groupings.

CHAPTER V IMPLICATIONS AND RECOMMENDATIONS

Implications

The results of this research imply that science teaching in the lower and middle elementary school grades should introduce science concepts with laboratory activities. The laboratory experiments can provide stimulating motivational experiences for concept learning in science.

Piaget's theory[34] of cognitive development states that students are progressing from a concrete operational stage to a formal logical operational at about adolescence. This research seems to confirm the idea that these changes are taking place in the mental development of fourth through sixth grade students. Teaching methods should be adjusted to capitalize on the changes. The recommendations are that laboratory experiences should be used to introduce science principles to fourth grade students but the development of theoretical concepts should be used to introduce science principles to sixth grade students. Since theoretical concepts are important in both grade levels, elementary school teacher education should include in-depth theoretical studies the biological, physical, and earth sciences. Also, inservice training and summer school science teaching improvement programs should focus on these basic foundations.

The results of this research may have implications for designers of the elementary science curriculum. There is an indication that laboratory experimentation plays a different role in the learning experiences of fourth and sixth grade students because the students are at different levels of cognitive development.

The increase in the majority of the delayed post test scores over the post test scores implies that science principles rather than science facts were learned by the students in both treatment groups. Frutchey[35] has published the results of an investigation of retention of high-school chemistry, in which tests designed to measure attainment in various educational objectives were administered at the beginning of the course, at the end of the course, and again a year later. The percentage of the gain retained in the application of principles was 92 percent. For knowledge of facts it was 84 percent and for chemical terminology it was 66 percent. Another study by Tyler[36] shows similar results.

Recommendations

It appears from the analysis of the data that this research design controlled many of the variables known to exist in educational research and it is recommended for

further studies in science education.

It is further recommended that research using the contrasting teaching methods of this study be conducted in biological science and earth science as well as other units in physical science. In the process of developing other units of instruction the designer should select a topic for which there are several laboratory experiments that clearly demonstrate the theoretical concepts associated with the unit of instruction and that the evaluation instrument adequately measure the effect of the laboratory and the theory equally.

This experimental design would have been strengthened if half of the fourth grade and half of the sixth grade students in each school system had received one of the contrasting instruction methods. This change would be possible in larger school systems with two or more learning centers. A different teaching method could be used at each grade level in the same system with a minimum amount of treatment contamination.

It is also recommended that a pre-test be included in the design and that a longer period of time be scheduled between the administration of the post and delayed post tests. By including the pre-test, a measure of the amount of gain due to the treatment could be obtained and the percentage of the gain retained after a period of six or eight months rather than the three month interval in this study would provide a better measure of retention due to the treatment.

The writer sincerely hopes this research will inspire other investigators to conduct similar studies in methods of teaching science.

APPENDICES

APPENDIX A

LESSON PLANS

APPENDIX A

LESSON PLANS

LABORATORY-THEORY SEQUENCE OF INSTRUCTION

Period I

Lesson Objective:

Given a box containing samples of ten different items, a magnifying glass and a magnet, the students should be able to describe orally the physical characteristics of each item, using identifying terms such as hardness, brittleness, color, luster, weight, magnetism, etc.

Concepts developed:

1. All materials have identifying characteristics.
2. Classes of materials have common characteristics.
3. Materials can be identified by these characteristics.

Activities:

1. Four beakers with earth, air, fire and water as ancient theory of elements.
2. Students inspected items in a box (3 students/box) with magnifier and magnet.
3. Described materials with such terms as hardness, color, luster, brittlemess, weight, magnetic, etc.
4. Each group selected one item from their box and listed its characteristics. The remainder of the class was asked to identify the item from this description.
5. Handed out folders for science materials.
6. Summary and review.

Period II

Lesson Objective:

Using a periodic chart, a flame, and selected chemicals, the students should be able to identify five chemical elements by a flame test or color change and describe these changes orally.

Concepts developed:

1. Each element has been named and given a chemical symbol.

2. There are about 103 known elements and 90 appear in nature.
3. Elements can be identified by certain tests (flame, color change, precipitation, etc.).

Activities:

1. Have one student at a time build a structure with wooden blocks and identify his structure for the class.
2. Use letters of alphabet and musical scale analogy of building blocks for language and music.
3. Perform flame test for chemical elements.
4. Two students demonstrated iodine and corn starch test.
5. Students demonstrated ammonia and commercial detector (phenothaline).
6. Summary and review.

Period III

Lesson Objective:

Using a magnifier, a magnet, a toothpick, water and a chromatograph, the students should be able to separate three mixtures of two or more materials.

Concepts developed:

1. Mixtures can be separated mechanically.
2. Compounds are new materials and cannot be separated mechanically.

Activities:

1. Each student given a magnifier, a mixture of salt and sand, a mixture of iron filings and sand, and a toothpick and asked to separate the salt and iron filings from the sand.
2. Each student given chromatograph kit and observed separation of materials by color.
3. Sharing time, summary and review.

Period IV

Given several common materials, a flame, and some water, the students should be able to identify and describe orally some of the characteristics associated with chemical changes and be capable of writing simple chemical compound formulas.

Concepts developed:

1. Chemical change always produces new materials.
2. Exchange of energy is associated with chemical change.

Activities:

1. Film: "Chemical Change" (11 min.) was shown.

2. Teacher demonstration of burning bread, wood, paper, and sugar.
3. Steel wool over water experiment was set-up, students predicted what would happen.
4. Sharing time, summary and review.

Period V

Lesson Objective:

Given a carbon dioxide indicator and a water indicator, the students should be capable of identifying these two chemical compounds and describing their observations verbally.

Concepts developed:

1. Water is in most dry materials.
2. One test for water is color change of dry copper sulfate.
3. The two elements in water can be separated by electrolysis.
4. Two methods of identifying the compound carbon dioxide.

Activities:

1. Set up electrolysis experiment and observe decomposition.
2. Dry copper sulfate on hot plate and note color change.
3. Dry pieces of chalk and collect water evaporated.
4. Have each child make the carbon dioxide test with either lime water or commercial indicator.
5. Set up long-range balloon and plastic bag for leakage experiments.
6. Observe steel wool experiment and discuss results.

Period VI

Lesson Objective:

Given several different materials the students should be able to divide each item into smaller and smaller pieces and describe orally the continuation of this dividing process down to the atomic level.

Concepts developed:

1. The particular nature of matter.
2. All matter is composed of atoms and molecules.

Activities:

1. A different student performed each of the following as a demonstration for the class:
   a) Cut iron wire in half and throw away half until remainder was too small to hold.
   b) Same cutting process with a sugar lump.
   c) Oil in water.
   d) Oil with detergent in water.

e) Water in atomizer.
f) Dissolve sugar, copper sulfate, potassium permangenate and Nestles Quick in water and filter solution.

2. Set up long range evaporation experiments using water, alcohol, and oil.
3. Damp sponge balanced on a meter stick experiment.
4. Set up long range solids for sublimation experiments.
5. Discussed the concepts of atoms and molecules as building blocks of matter.

Period VII

Lesson Objective:

Using large crystaline models and a raft of soap bubbles, the students should be able to describe orally the structures of simple solids using the concepts of atoms and molecules.

Concepts developed:

1. Many solids have crystalline shapes.
2. Six basic crystalline structures.
3. Atoms and molecules are very, very small.

Activities:

1. View film, "The World of Molecules," (11 min.).
2. Set up sugar crystal growing experiment.
3. Each student had a small dish to perform the bubble raft experiment.
4. Passed out samples of six crystalline structures.
5. Listed and discussed size of atoms and molecules using a series of examples of common materials (sand, water, raindrop, etc.).

Period VIII

Lesson Objective:

Using inflated balloons and plastic bags held in an atmosphere of perfume, vanilla extract, etc., and mixing sugar with water, the students should be able to describe verbally how these materials could penetrate and mix without a corresponding change in volume.

Concepts developed:

There are tiny spaces between the molecules that make up a substance.

Activities:

1. Inflated balloons and plastic bags with air over perfume, ammonia water, vanilla extract and chlorine water.
2. Set up ammonia indicator in plastic bag over ammonia water.

3. Passed out samples of marbles, B-B shot and sand as indications of spaces between molecules.
4. Performed experiment of dissolving 50 cc of sugar in 300 cc of water for a total volume change of 325 cc of solution.
5. Observed changes in length of inflated balloon and plastic bag experiment set up during Period V.
6. Sharing student collections and lesson review.

Period IX

Lesson Objective:

Using the concept of the particulate nature of matter the students should be able to describe verbally a theoretical atomic structure consistent with their observations.

Concepts developed:

1. Atoms are composed of two different kinds of charged particles.
2. Individual charged particles exert forces on other charged particles.
3. Charged particles are named electrons and protons.
4. A third particle exists called a neutron.

Activities:

1. Observed and discussed the observed changes in all the extended time experiments. (Balloons, plastic bags, evaporation, etc.).
2. Slide projector as model of electron microscope for looking at tiny particles.
3. Each student performed the charged paper strips experiment.
4. Students demonstrated hard rubber, glass, fur and silk charging experiments.
5. Discussed atomic theories and handed out sheet describing atomic structure of first eight elements on periodic chart.
6. Summary of concepts developed.

Period X

Lesson Objectives:

Given styrofoam balls and pipe stem cleaners, the students should be able to build an atomic model of one of the first eight elements on the periodic chart and describe their structure verbally.

Concepts developed:

1. The basic forces in our world.
2. The structure of atoms.
3. The significance of the atomic number, atomic weight, number of electrons, protons and neutrons in an atom.
4. The relative size of electrons, protons, and neutrons.

5. The structure of simple molecules.

Activities:

1. Viewed film, "Forces," (12 min.).
2. Each student constructed an atom using styrofoam balls and pipe stem cleaners.
3. Performed heated ball and ring experiment.
4. Built water molecule with styrofoam balls and pipe stem cleaners.
5. Discussed method of writing chemical formulas for simple compounds.
6. Passed out sheet describing the proton and showing molecular models.
7. Summary and description evaluation procedure.

THEORY-LABORATORY SEQUENCE OF INSTRUCTION

Period I

Lesson Objective:

Using familiar examples of common forces and the film entitled "Forces" the students should be able to identify and describe verbally at least three of the fundamental forces of the universe.

Concepts developed:

1. The concept of a fundamental force.
2. The fundamental forces of our world (gravity, electric, magnetic, nuclear).

Activities:

1. Gave each student a folder for science materials.
2. Introduced the topic and explained classroom procedure.
3. Students listed fundamental forces on a sheet of paper. (Students shared their list with the class, one at a time.)
4. Film entitled, "Forces," was shown and reviewed.
5. Instructor demonstrated electric, magnetic and gravitational forces.

Period II

Lesson Objective:

Using the modern description of electrons, protons, and neutrons, the students should be capable of describing the interacting characteristics of these three fundamental particles.

Concepts developed:

1. Identify the fundamental particles of matter (proton, neutron, electron).

2. The relative weight or mass of each particle.
3. The magnitude and sign of the charge on each particle.

Activities:

1. Reviewed fundamental forces.
2. Looked at beakers of air, earth, fire and water as ancient view of elements.
3. Explained modern theory of matter.
4. Described characteristics of three elementary particles (mass and charge).
5. Shared student collections, summary and review.

Period III

Lesson Objective:

Using the fundamental particles and the periodic chart the students should be able to verbally describe the composition of the first eight elements on the periodic chart.

Concepts developed:

1. The atomic model of the atom.
2. Definitions of element, atom, molecule, ion nucleus, etc.
3. The systematic way the particles are organized to form the 103 elements on the periodic chart. (Include interpreting the various numbers.)

Activities:

1. Conducted a review session of forces and particles.
2. Described possible arrangements of fundamental particles.
3. Described elements and the meaning of the numbers on the periodic chart.
4. Gave each student a small periodic chart for their science folder.

Period IV

Lesson Objective:

Given a list and description of the known chemical elements, the students should be capable of verbally describing elements, compounds, and mixtures and be able to write simple compound formulas.

Concepts developed:

1. The molecule as a combination of two or more atoms.
2. Molecular motion in gases, liquids and solids.
3. Chemical compounds and mixtures.

Activities:

1. Reviewed forces, particles and atomic structure theory.

2. Described the three states of matter (gas, liquid and solid).
3. Described the differences between mixtures and compounds.
4. Described atomic structure of compounds.
5. Described short hand method of writing formulas for chemical compounds.
6. Showed film, "World of Molecules," (11 min.).
7. Gave each student a description of the proton and sketches of molecular structure.

Period V

Lesson Objective:

Given styrofoam balls and pipe stem cleaners the students should be able to construct an atomic model of one of the first eight elements on the periodic chart and describe their structure verbally.

Concepts developed:

1. The size and number of molecules in a drop of water and grain of sand.
2. Size of the spaces between atoms and molecules in a gas, liquid, and solid.
3. Increased molecular motion with temperature rise.

Activities:

1. Reviewed atomic structure.
2. Listed approximate number of molecules in drop of water, grain of sand, etc.
3. Passed around samples of marbles, B-B shot and sand as example of spaces between molecules.
4. Heated ball and ring and discussed what parts of the atomic structure were expanding.
5. Each student constructed a model of a simple chemical element using styrofoam balls and pipe stem cleaners. (A water molecule was also built.)

Period VI

Lesson Objective:

Using a magnifier, a magnet, a toothpick, water and a chromatograph, the students should be able to separate three mixtures of two or more materials.

Concepts developed:

1. Different materials have different physical characteristics.
2. Mixture can be separated mechanically.
3. No new material is formed in a mixture.

Activities:

1. Each student separated sand from sugar and iron filings from sand with toothpick and magnifier.
2. Each child asked to describe physical characteristics of a sample of material.
3. Class performed the chromatograph experiment as method of separating mixtures.
4. Long range balloon experiment was set up.
5. Summary and lesson review.

Period VII

Lesson Objective:

Using a flame and selected chemical compounds the students should be capable of identifying chemical elements by the flame test or color change and should be able to describe orally some of the characteristics associated with chemical change.

Concepts developed:

1. Specific elements can be identified by certain tests.
2. A new and different material if formed in a chemical change.
3. The original material is used up in a chemical change.

Activities:

1. Used wooden blocks, musical notes and letters of alphabet as examples of fundamental building block for a particular system.
2. Identified several chemical elements using the flame test.
3. Two students demonstrated corn starch and iodine identification.
4. Identified ammonia using phenothaline indicator.
5. Burned wood, bread, paper and sugar as examples of chemical change.
6. Each student performed the carbon dioxide test with either lime water or commercial indicator.
7. Set up the steel wool over water experiment.
8. Summary and discussion of theories associated with observations.

Period VIII

Lesson Objective:

Given a carbon dioxide indicator and a water indicator and several materials that evaporate readily, the students should be capable of identifying water and carbon dioxide and verbally explaining evaporation and sublimation.

Concepts developed:

1. One method of identifying water.

2. One method of separating water into two gases.
3. Water is in dry materials.

Activities:

1. Separated water by electrolysis.
2. Damp sponge balanced on meter stick experiment.
3. Dry copper sulfate water indicator test.
4. Set up sugar crystal growing experiment.
5. Set up inflated balloon and plastic bag experiments over perfume, ammonia, vanilla, etc.
6. Set up evaporation and sublimation experiments.
7. Summary and discussion (questions and answers) of relationship of atomic theory to observations in this lesson.

Period IX

Lesson Objective:

Given several different materials the students should be able to divide these materials into smaller and smaller pieces and then verbally describe the continuation of this process to the atomic level.

Concepts developed:

1. The particulate nature of matter.
2. Dissolved particles and spaces between molecules.
3. The differences between physical and chemical changes.

Activities:

1. Viewed film, "Chemical Change," (11 min.) and discussed important concepts presented.
2. Student demonstration of cutting iron wire, sugar cube, water, etc. in one-half and discarding half until too small to continue.
3. Dissolved 50 cc of sugar in 300 cc of water and measured 325 cc of solution.
4. Dissolved sugar, potassium permanginate, copper sulfate and Nestles Quick in water and filtered.
5. Discussed steel wool over water experiment and discussed the atomic level considerations associated with the experiment.
6. Summary and review with student sharing collections and other science interests.

Period X

Lesson Objective:

Using large crystaline models and a raft of soap bubbles the students should be able to describe orally the structures of simple solids using the concepts of atoms and molecules.

Concepts developed:

1. There are spaces between the particles of all matter.
2. Molecules of some solids are arranged in certain crystalling structures.
3. Evidences of atomic structure are indirect.

Activities:

1. Observes and discussed all the long range experiments.
2. Described ways scientists look at tiny particles.
3. Described samples of six basic crystalline structures.
4. Students performed bubble raft experiment as model of crystalline structure.
5. Summary and review of entire unit.
6. Discussed evaluation instrument (purpose and method of administration).

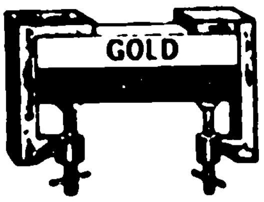
APPENDIX B

ACHIEVEMENT TEST INSTRUMENT

ACHIEVEMENT TEST INSTRUMENT

Read the following paragraph about a scientific experiment carefully.

In an experiment, two pieces of pure lead and gold with very clean surfaces were brought into contact and clamped tightly together. After four years, at normal temperatures, lead was detected at a depth of 3/16 inch in the gold. On the other hand, at a depth of 1/32 of an inch in the lead there was enough gold to have paid to extract it if done on a large scale. Thus, although lead and gold are solids at normal temperatures, the two solids tended to mix over the four year period of time. At 500°C gold spreads through lead about as fast as common salt spreads through water at 18°C.



Now consider each of the following statements about the experiment and in the blank before each statement write the number.

1. if you believe that the data in the experiment alone prove the statement true

2. if you believe that the data in the experiment alone suggest that the statement is probably true but do not definitely prove it

3. if you believe that the data in the experiment alone are not enough to make a decision about the statement

4. if you believe that the data in the experiment alone suggest that the statement is probably false but do not definitely prove it, and

5. if you believe that the data in the experiment alone contradict the statement and prove it false

1._______ Impurities in gold make such gold less valuable than pure gold.

2._______ Silver, if placed with lead for a period of four years, could be detected at a depth of 3/16 inch in the lead.

COMPARISONS

Compare the idea or statement on the LEFT with the idea or statement on the RIGHT and then check your answer in the ANSWER column.

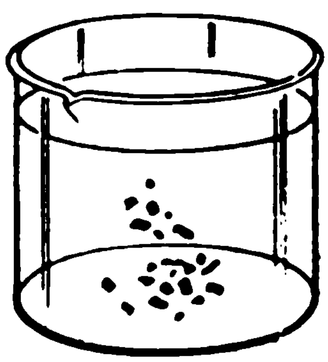
LEFT	ANSWER	RIGHT
3. Force with which a + charge attracts a - charge	____ is greater than ____ is the same as ____ is less than	Force with which a - charge attracts a + charge
4. Number of atoms in $Al\ Cl_3$	____ is greater than ____ is the same as ____ is less than	Number of atoms in $Na_2\ SO_4$
5. Number of different kinds of atoms found in H_2O	____ is greater than ____ is the same as ____ is less than	Number of different atoms found in Na Cl
6. Amount of sugar capable of being dissolved in a given quantity of cold water	____ is greater than ____ is the same as ____ is less than	Amount of sugar capable of being dissolved in the same amount of hot water
7. Amount of molecular movement in a substance at a high temperature	____ is greater than ____ is the same as ____ is less than	Amount of molecular movement in same substance at a lower temperature
8. Ability of light to penetrate paper	____ is greater than ____ is the same as ____ is less than	Ability of X-rays to penetrate paper
9. Weight of a proton	____ is greater than ____ is the same as ____ is less than	Weight of an electron
10. Number of atoms in a grain of sand	____ is greater than ____ is the same as ____ is less than	Number of atoms in a rock
11. Speed of proton	____ is greater than ____ is the same as ____ is less than	Speed of electron
12. Number of protons in a neutral helium atom	____ is greater than ____ is the same as ____ is less than	Number of electrons in a neutral helium atom
13. Number of protons in a helium atom	____ is greater than ____ is the same as ____ is less than	Number of protons in a hydrogen atom

COMPARISONS (Continued)

LEFT	ANSWER	RIGHT
14. Atomic number of an element	____ is greater than ____ is the same as ____ is less than	Number of electrons in a neutral atom of the same element
15. Ease with which electrons can be brushed off an atom	____ is greater than ____ is the same as ____ is less than	Ease with which protons can be brushed off an atom
16. Number of electrons on positive hydrogen ion	____ is greater than ____ is the same as ____ is less than	Number of electrons on neutral hydrogen atom

EXPLAINING WHAT IS OBSERVED

A good deal of science is observing things that happen and then explaining them. What do you think about the various explanations?



17. Observation: Several crystals of potassium permanganate were dropped into a large beaker of water. At first small streams of purple color spread out from the crystals. After several hours the colorless water had been changed to a uniform purple color.

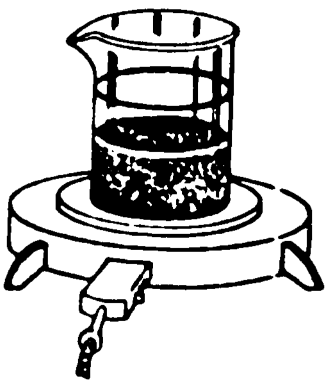
Jane said, "I think that the crystals of potassium permanganate break up into countless millions of pieces. These pieces have a purple color. The potassium permanganate pieces mix evenly among the colorless water atoms and thus give the solution a purple color."

Ted said, "I think that the potassium permanganate colored the water atoms purple. All water atoms are changed into purple atoms at the end of the experiment and they cannot be made colorless again.

EXPLAINING WHAT IS OBSERVED (Continued)

What do you think?

____Agree with Ted but disagree with Jane.
____Agree with Jane but disagree with Ted.
____Agree with both Ted and Jane.
____Disagree with both Ted and Jane.
____Am not sure.



18. Observation: Water is placed in a beaker and the level marked with a crayon. The beaker is placed on a hot plate and the water brought to a boil. After several minutes the beaker is removed from the hot plate and the water allowed to cool. The water level is observed to be below the crayon mark.

John said: "I think that the heat from the hot plate burned some of the water. Water is made up of hydrogen and oxygen. Oxygen supports burning."

What do you think?

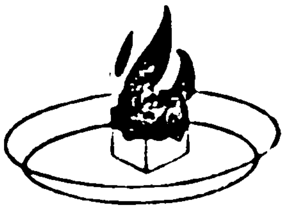
____Agree with everything said.
____Agree with some things John said but disagree with others.
____Disagree with everything John said.
____Am not sure.

---

19. Observation: When a piece of paper is burned a black substance is left. When a match is burned a black substance is left. When a lump of sugar is burned a black substance is left.

Mary said, "I think the black substance left is the same with each thing burned. It is carbon."

Tim said, "I think that the black substance left in each case is different. Since paper, wood, and sugar are not alike, they cannot have the same natural elements in them."



What do you think?

_____Agree with Mary but disagree with Tim.
_____Agree with Tim but disagree with Mary.
_____Disagree with both Mary and Tim.
_____Am not sure.

---

20. Observation: Some substances are made of crystals. The shapes of many such substances have smooth flat sides, sharp edges, and pointed corners. When a substance made of crystals is broken, it often breaks in a definite way where the smaller pieces still resemble the original shape.

Now consider the following substances: salt, glass, and wood.

What do you think?

_____Only salt is made of crystals.
_____All the substances are made of crystals.
_____None of the substances are made of crystals.
_____All the substances except glass are made of crystals.
_____Am not sure.

---

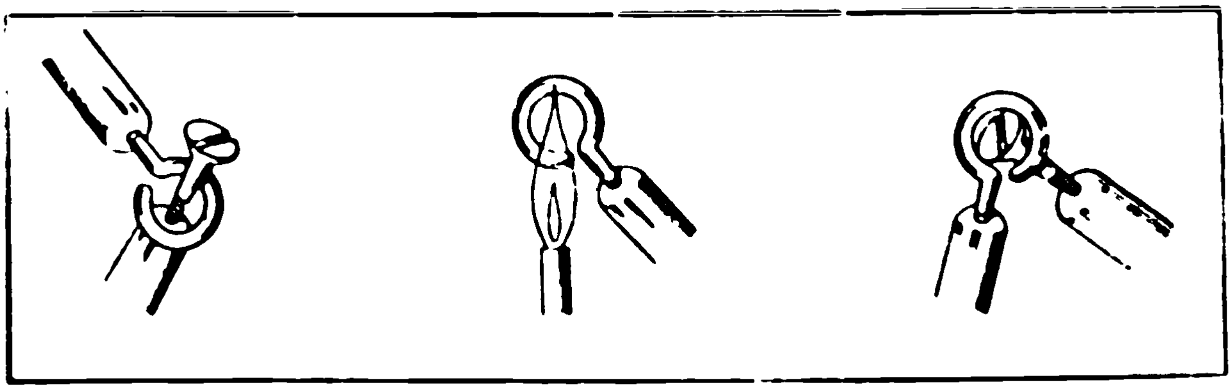
21. Observation: A solvent can hold only a certain amount of a solute. When it holds all that it can, the solution is said to be saturated.

Which of the following ways do you think might be the best way to get more of a solute into solution?

_____Pour the solution into a larger container and add more of the solute.
_____Heat the solution and add more of the solute.
_____Cool the solution and add more of the solute.
_____Grind the solute into finer particles and add to the solution.
_____Pour the solution through a cloth, separate the crystals, and suspend the crystals in the solution and watch them grow.
_____It is impossible to get more of the solute into solution.

EXPLAINING WHAT IS OBSERVED (Continued)

22. Observation: Most substances expand when heated and contract when cooled.



Sue said, "I think that heat causes molecules to move faster. As they move faster they occupy more space. Thus, heat tends to make things expand."

Tom said, "I think that heat makes the molecules bigger and this makes things expand."

Ann said, "I think that heat is a kind of substance. Hot things have more heat. Therefore, hot things have the molecules and the heat, which makes them larger."

What do you think?

_____Agree with Sue but not Tom or Ann.
_____Agree with Tom but not Sue or Ann.
_____Agree with Ann but not Tom or Sue.
_____Disagree with Sue, Tom, and Ann.
_____Am not sure.

FACT AND THEORY

Science is made up of a lot of facts and theories. Facts are what we can observe and measure. Theories are explanations as to why the facts occur. In addition, scientists use definitions or terms which they agree upon in order to describe facts and theories. Consider each of the following statements and in the blank write the letter.

F. if you think the statement is a fact.
T. if you think the statement is a theory.
D. if you think the statement is neither fact nor theory but is a definition or term agreed upon by scientists.

23. _____The charge on protons is positive and the charge on electrons is negative.

FACT AND THEORY (Continued)

24. _____An atom is made up of heavy center parts called protons surrounded by electrons.

25. _____The physical properties of a substance remain the same regardless of the quantity of the substance.

26. _____One substance can be unlike another substance.

27. _____Elements may be broken into smaller units.

28. _____Eleven molecules of water are written as 11 H_2O and not as $H_{22}O_{11}$.

29. _____Atoms and molecules are in continuous motion.

30. _____Atoms cannot be seen.

31. _____Substances put in a flame give the flame a characteristic color.

32. _____Heated molecules have more space among them.

33. _____The number given to an atom is called an atomic number.

34. _____A solvent can hold only a certain amount of a solute.

ELEMENTS AND COMPOUNDS

Consider each of the following statements and in the blank write the number.

1. if the statement applies to elements only.
2. if the statement applies to compounds only.
3. if the statement applies to both elements and compounds.
4. if the statement applies to neither elements nor compounds.

35. _____Has physical properties characteristic of the substance.

36. _____Pure and not formed by combination with other substances.

37. _____Has weight.

38. _____Contains electrons and protons.

39. _____May form crystals.

40. _____Can be illustrated by a model.

ELEMENTS AND COMPOUNDS (Continued)

41. ____Substance has an atomic number.

42. ____Found in a natural state in and around the earth.

43. ____Always has a positive or negative charge.

44. ____Occurs only as a solid.

NATURE OF PROOF

The atomic theory of matter makes four basic assumptions.

- Matter is composed of exceedingly small, separate particles.
- Each kind of matter is made up of its own particular kind of particles.
- The particles are in rapid and ceaseless motion.
- The particles can attract each other.

Consider each of the following statements and in the blank write the number.

1. if the statement is true and supports the atomic theory.
2. if the statement is true but neither supports nor contradicts the atomic theory, and
3. if the statement is false.

45. ____If a few crystals of a substance are dropped into a liquid in which it is soluble, the substance will diffuse throughout the liquid.

46. ____The atomic number indicates how many electrons, protons, and neutrons an atom has.

47. ____Some substances have characteristic colors.

48. ____Certain substances will burn.

49. ____Neutral atoms have excess positive or negative charges.

50. ____Atoms can be seen under powerful microscopes.

51. ____The smallest pieces of a substance have different properties from larger pieces of the same substance.

APPLICATION OF PRINCIPLES

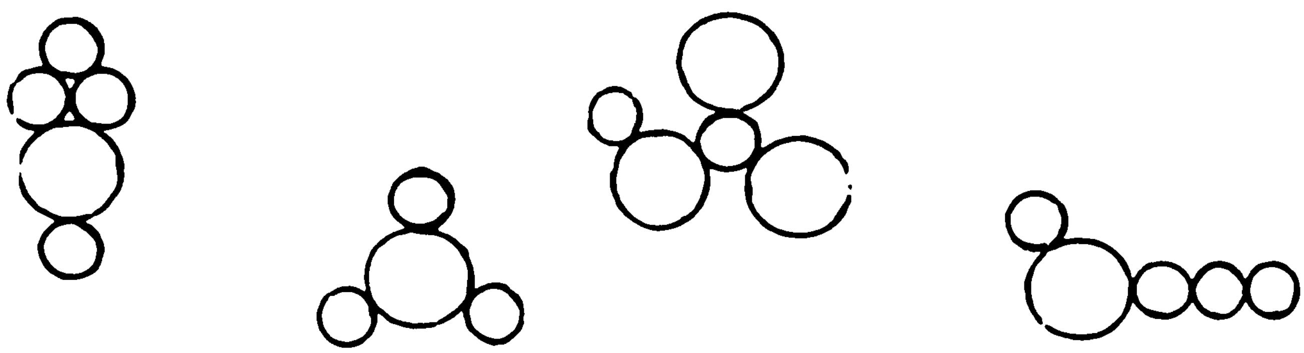
Consider each of the following and check the answer which you think best.

APPLICATION OF PRINCIPLES (Continued)

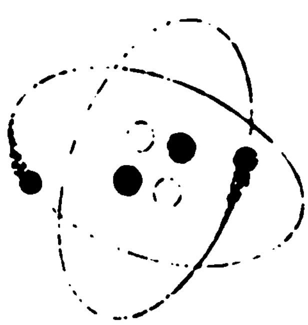
52. A molecule of ammonia is formed by one nitrogen (N) atom and three hydrogen (H) atoms. Which of the following is the best formula for ammonia?

____NHHH
____H_3N
____NH_3
____$(NH)H_2$

53. Which is the best model to illustrate a molecule of ammonia?

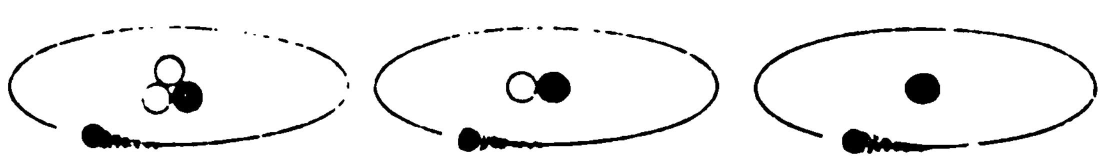


54. In the following model of an atom, how many electrons are shown?



____1 electron
____2 electrons
____3 electrons
____4 electrons
____5 electrons
____6 electrons

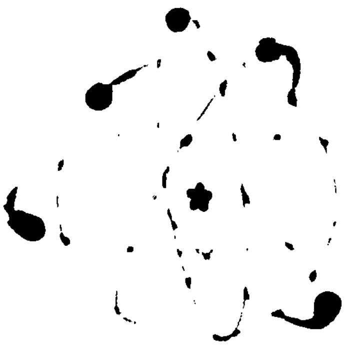
55. Here are three different models of various forms of hydrogen. Which one shows hydrogen in its simplest form?



56. Sugar is composed of twelve atoms of carbon (C), twenty-two atoms of hydrogen (H), and eleven atoms of oxygen (O). Which formula is the simplest one for sugar?

____$12C11(H_2O)$
____$C_{12}11H_2O$
____$C_{12}H_{22}O_{11}$
____$6(C_2H_{11})O_{11}$

57. Here are two models of the same atom under different conditions



A

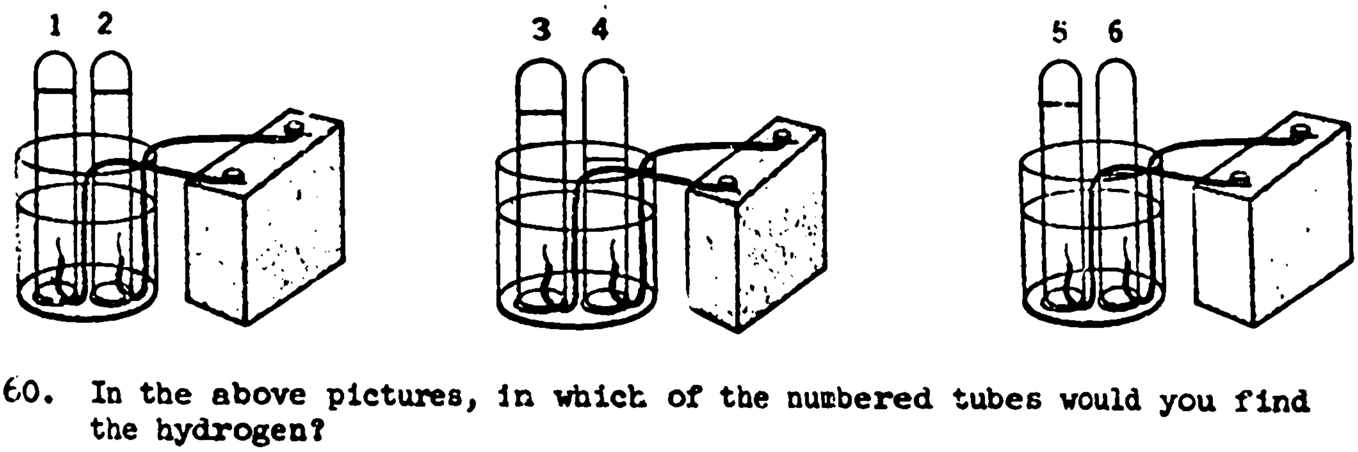
B

_____If Model A is neutral the charge on Model B is plus one.
_____If Model A is neutral the charge on Model B is minus one.
_____The charge on Models A and B are the same.
_____The charge on the cluster in the center of the two models is different

58. One ounce of ink is placed in a beaker. Half the solution is poured out. Pure water is added to the original level. The solution is mixed, and half poured out again. This process is repeated several times. If 1/32 ounce of the ink remains in the solution, what is the number of times half the solution was poured out?

_____2
_____3
_____5
_____8
_____32

59. An experiment was set up to break down water into its two elements, hydrogen and oxygen. Which illustration shows the experiment to be working properly?



60. In the above pictures, in which of the numbered tubes would you find the hydrogen?

_____1
_____2
_____3
_____4
_____5
_____6

APPENDIX C

ELEMENTARY SCHOOL SCIENCE TEXT SERIES EXAMINED

APPENDIX C

SCIENCE TEXTBOOK SERIES

Blough, Glenn O. and others. The Basic Science Program. Chicago: Scott, Foresman, and Co., 1965.

Grade 4: Science is Experimenting
Grade 5: Science is Discovering
Grade 6: Science is Adventuring

Brandwein, Paul F. and others. Comprehensive Science Program. New York: Harcourt, Brace, and World Inc., 1966.

Grade 4: Concepts in Science 4
Grade 5: Concepts in Science 5
Grade 6: Concepts in Science 6

Craig, Gerald S. and others. Science Today and Tomorrow Series. New York Ginn and Company, 1965.

Grade 4: Discovering with Science
Grade 5: Adventuring with Science
Grade 6: Experimenting with Science

Fischler, Abraham S. and others. Modern Science Series. Holt, Rinehart & Winston, Inc., New York, 1966.

Grade 4: Science / A Modern Approach
Grade 5: Science / A Modern Approach
Grade 6: Science / A Modern Approach

Jacobson, Willard J. and others. American Book Company Series. American Book Company, New York: 1965.

Grade 4: Probing Into Science
Grade 5: Inquiring Into Science
Grade 6: Investigating In Science

Mallinson, George G. and others. The Silver Burdett Science Program.
Morristown, New Jersey. The Silver Burdett Co., [illegible].

Grade 4: Science 4
Grade 5: Science 5
Grade 6: Science 6

Navarra, John G., and Zafforoni, Joseph. Today's Basic Science Series.
New York Harper and Row, 1967.

Grade 4: Today's Basic Science Series 4
Grade 5: Today's Basic Science Series 5
Grade 6: Today's Basic Science Series 6

Schneider, Herman, and Nina Schneider. Heath Science Series.
Boston: D. C. Heath & Co., 1965.

Grade 4: Science in Your Life
Grade 5: Science in Our World
Grade 6: Science for Today and Tomorrow

Smith, Herbert A and others. The Laidlaw Science Series. River
Forest, Illinois: Laidlaw Brothers, 1966.

Grade 4: Science 4
Grade 5: Science 5
Grade 6: Science 6

Thurber, Walter A., and Mary C. Durkee. Exploring Science Series.
Chicago: Allyn & Bacon, Inc., 1964.

Grade 4: Exploring Science 4
Grade 5: Exploring Science 5
Grade 6: Exploring Science 6

APPENDIX D

ACHIEVEMENT TEST INSTRUMENT ITEM ANALYSIS

TABLE 1

ITEM RESPONSE FOR FOURTH AND SIXTH GRADES
IN PER CENT CORRECT RESPONSES
BY METHOD OF INSTRUCTION

Item Number	Fourth Grade		Sixth Grade	
	Lab-Theory	Theory-Lab	Lab-Theory	Theory-Lab
1	11	23	23	16
2	15	19	37	14
3	26	41	52	71
4	53	48	69	77
5	36	22	27	22
6	45	57	75	71
7	48	63	88	80
8	57	47	60	59
9	38	47	46	65
10	57	48	63	62
11	26	33	37	42
12	40	28	35	53
13	47	38	44	47
14	38	43	44	56
15	32	29	31	32
16	49	35	31	41
17	36	38	71	58
18	68	43	71	66
19	79	63	88	81
20	49	39	73	68
21	15	22	50	35
22	36	52	71	77
23	21	16	19	16
24	36	39	23	30
25	36	29	42	34
26	47	47	46	59
27	64	38	62	57
28	40	32	33	35
29	36	39	35	22
30	57	46	81	68

TABLE [illegible] (Continued)

Item Number	Fourth Grade		Sixth Grade	
	Lab-Theory	Theory-Lab	Lab-Theory	Theory-Lab
31	55	49	60	73
32	40	38	31	27
33	30	24	38	23
34	45	33	69	63
35	29	22	35	23
36	32	39	67	57
37	43	27	62	63
38	16	41	42	65
39	30	18	21	30
40	34	30	60	42
41	45	29	37	48
42	23	34	40	29
43	17	13	15	20
44	32	28	42	48
45	19	37	38	46
46	15	15	12	10
47	36	34	38	54
48	40	38	44	39
49	21	29	17	44
50	74	49	73	49
51	40	27	46	35
52	36	47	88	59
53	38	59	77	78
54	36	24	52	63
55	77	53	65	81
56	64	75	88	92
57	6	18	13	5
58	15	14	17	14
59	64	42	60	53
60	30	41	48	61

TABLE 2

CHI SQUARE ITEM ANALYSIS COMPARING ITEM RESPONSES
WITH THE METHOD OF INSTRUCTION (df = 1)

Item Number	Response	Laboratory-Theory Total	Laboratory-Theory Per Cent	Theory-Laboratory Total	Theory-Laboratory Per Cent	Chi Square
1	Wrong	82	83	127	80	0.24
	Right	17	17	31	20	
2	Wrong	73	74	132	84	3.63
	Right	26	26	26	16	
3	Wrong	60	61	70	44	6.47*
	Right	39	39	88	56	
4	Wrong	38	38	59	37	0.03
	Right	61	62	99	63	
5	Wrong	68	69	124	78	3.09
	Right	31	31	34	22	
6	Wrong	39	39	57	36	0.29
	Right	60	61	101	64	
7	Wrong	21	21	45	28	1.68
	Right	78	79	113	72	
8	Wrong	41	41	74	47	0.72
	Right	58	59	84	53	
9	Wrong	57	58	70	44	4.29*
	Right	42	42	88	56	
10	Wrong	39	39	71	45	0.76
	Right	60	61	87	55	
11	Wrong	68	69	99	63	0.97
	Right	31	31	59	37	
12	Wrong	62	63	94	59	0.25
	Right	37	37	64	41	
13	Wrong	54	55	91	58	0.23
	Right	45	45	67	42	
14	Wrong	58	59	80	51	1.55
	Right	41	41	78	49	

**$p<.01$ $\chi^2 = 6.64$
*$p<.05$ $\chi^2 = 3.84$

TABLE 2 (Continued)

Item Number	Response	Laboratory-Theory		Theory-Laboratory		Chi Square
		Total	Per Cent	Total	Per Cent	
15	Wrong	68	69	110	70	0.02
	Right	31	31	48	30	
16	Wrong	60	61	98	62	0.05
	Right	39	39	60	38	
17	Wrong	45	45	82	52	1.01
	Right	54	55	76	48	
18	Wrong	30	30	72	46	5.93*
	Right	69	70	86	54	
19	Wrong	16	16	44	28	4.64*
	Right	83	84	114	72	
20	Wrong	38	38	73	46	1.52
	Right	61	62	85	54	
21	Wrong	66	67	113	72	0.68
	Right	33	33	45	28	
22	Wrong	45	45	56	35	2.56
	Right	54	55	102	65	
23	Wrong	79	80	132	84	0.58
	Right	20	20	26	16	
24	Wrong	70	71	103	65	0.84
	Right	29	29	55	35	
25	Wrong	60	61	108	68	1.61
	Right	39	39	50	32	
26	Wrong	53	54	74	47	1.09
	Right	46	46	84	53	
27	Wrong	37	37	83	53	5.62*
	Right	62	63	75	47	
28	Wrong	63	64	105	66	0.21
	Right	36	36	53	34	
29	Wrong	64	65	110	70	0.69
	Right	35	35	48	30	

**$p<.01$ $X^2 = 6.64$
*$p<.05$ $X^2 = 3.84$

TABLE 2 (Continued)

Item Number	Response	Laboratory-Theory Total	Laboratory-Theory Per Cent	Theory-Laboratory Total	Theory-Laboratory Per Cent	Chi Square
30	Wrong	30	30	68	43	4.18*
	Right	69	70	90	57	
31	Wrong	42	42	61	39	0.37
	Right	57	58	97	61	
32	Wrong	64	65	107	68	0.26
	Right	35	35	51	32	
33	Wrong	65	66	121	77	3.63
	Right	34	34	37	23	
34	Wrong	42	42	82	52	2.19
	Right	57	58	76	48	
35	Wrong	72	73	123	78	0.87
	Right	27	27	35	22	
36	Wrong	49	49	82	52	0.14
	Right	50	51	76	48	
37	Wrong	47	47	86	54	1.18
	Right	52	53	72	46	
38	Wrong	60	61	75	47	4.21*
	Right	39	39	83	53	
39	Wrong	74	75	120	76	0.05
	Right	25	25	38	24	
40	Wrong	52	53	101	64	3.28
	Right	47	47	57	36	
41	Wrong	59	60	97	61	0.08
	Right	40	40	61	39	
42	Wrong	67	68	108	68	0.01
	Right	32	32	50	32	
43	Wrong	83	84	132	84	0.00
	Right	16	16	26	16	
44	Wrong	62	63	98	62	0.01
	Right	37	37	60	38	
45	Wrong	70	71	93	59	3.68
	Right	29	29	65	41	

**$p<.01$ $X^2 = 6.64$
*$p<.05$ $X^2 = 3.84$

TABLE 2 (Continued)

Item Number	Response	Laboratory-Theory		Theory-Laboratory		Chi Square
		Total	Per Cent	Total	Per Cent	
46	Wrong	86	87	138	87	0.01
	Right	13	13	20	13	
47	Wrong	62	63	88	56	1.20
	Right	37	37	70	44	
48	Wrong	57	58	97	61	0.37
	Right	42	42	61	39	
49	Wrong	80	81	100	63	8.90**
	Right	19	19	58	37	
50	Wrong	26	26	80	51	14.92**
	Right	73	74	78	49	
51	Wrong	56	57	109	69	4.09*
	Right	43	43	49	31	
52	Wrong	36	36	74	47	2.73
	Right	63	64	84	53	
53	Wrong	41	41	49	31	2.89
	Right	58	59	109	69	
54	Wrong	55	56	89	56	0.01
	Right	44	44	69	44	
55	Wrong	29	29	52	33	0.37
	Right	70	71	106	67	
56	Wrong	23	23	26	16	1.81
	Right	76	77	132	84	
57	Wrong	89	90	140	89	0.10
	Right	10	10	18	11	
58	Wrong	83	84	136	86	0.24
	Right	16	16	22	14	
59	Wrong	38	38	83	53	4.89*
	Right	61	62	75	47	
60	Wrong	60	61	78	49	3.09
	Right	39	39	80	51	

**$p<.01$ $X^2 = 6.64$
*$p<.05$ $X^2 = 3.84$

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